



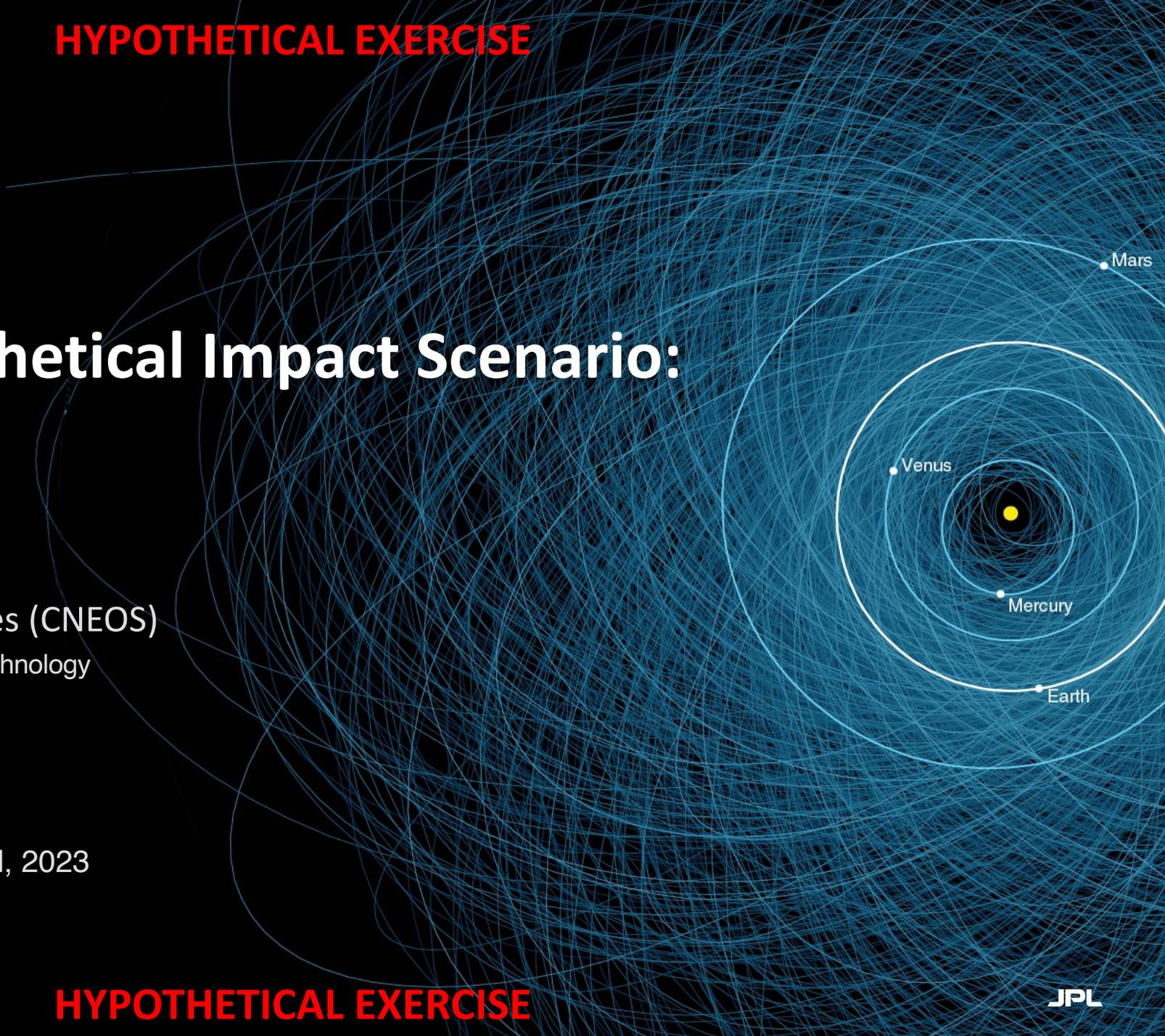
HYPOTHETICAL EXERCISE

The 2023 PDC Hypothetical Impact Scenario: Epoch 1 Summary

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Asteroid 2023 PDC: Initial Discovery & Tracking

- New asteroid discovered on Jan. 10, 2023 by an international team using the Dark Energy Camera (DECCam) searching in the twilight region of the sky, looking for asteroids in the inner Solar System
- After confirmation, the Minor Planet Center assigned the asteroid the designation “2023 PDC”
- Based on its apparent brightness the asteroid’s absolute magnitude H is determined to be 19.4
- Since its orbit approaches to within 0.05 au of Earth’s orbit, 2023 PDC is designated as a PHA
- Additionally, after only a few days of tracking CNEOS determined that 2023 PDC has a one-in-ten-thousand chance of impacting Earth in the year 2036; ESA’s NEOCC reaches a similar conclusion
- Over the next 3 months, orbit uncertainty decreases and impact probability rises, and now reaching **1%**
- If the asteroid is on a collision course, the impact would occur on Oct. 22, 2036, **13 years from now**
- Little is known about the 2023 PDC’s size, but based on its absolute magnitude, it could be quite large
- Allowing for uncertainties in H and a full range of possible albedos (reflectivities), 2023 PDC’s size is most likely in the range **220 - 660 meters** (720 - 2200 feet), but there is a small chance that it is larger than 1 kilometer (0.6 miles) in size
- If 2023 PDC should impact, the energy it would release is most likely in the range **54 Mt - 5.5 Gt**

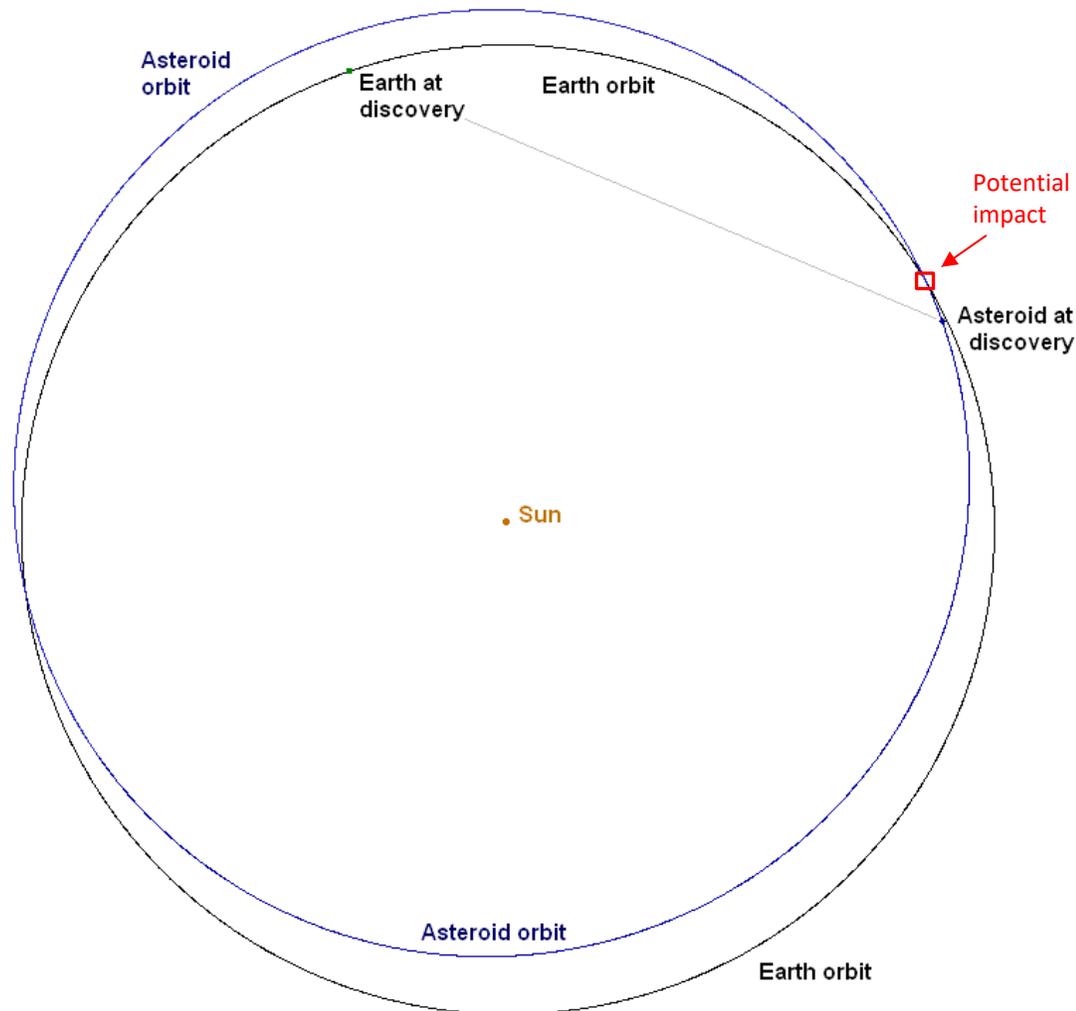


Potential 2023 PDC Impact in Context of Expected Events

| Diameter of Impacting Asteroid | Type of Event | Approximate Impact Energy (MT) | Average Time Between Impacts (Years) |
|--------------------------------|------------------------------------|--------------------------------|--------------------------------------|
| 5 m (16 ft) | Bolide | 0.01 | 1 |
| 10 m (33 ft) | Superbolide | 0.1 | 10 |
| 25 m (80 ft) | Major Airburst | 1 | 100 |
| 50 m (160 ft) | Local Scale Devastation | 10 | 1000 |
| 140 m (460 ft) | Regional Scale Devastation | 300 | 20,000 |
| 300 m (1000 ft) | Continent Scale Devastation | 2,000 | 70,000 |
| 600 m (2000 ft) | Below Global Catastrophe Threshold | 20,000 | 200,000 |
| 1 km (3300 ft) | Possible Global Catastrophe | 100,000 | 700,000 |
| 5 km (3 mi) | Above Global Catastrophe Threshold | 10,000,000 | 30 million |
| 10 km (6 mi) | Mass Extinction | 100,000,000 | 100 million |



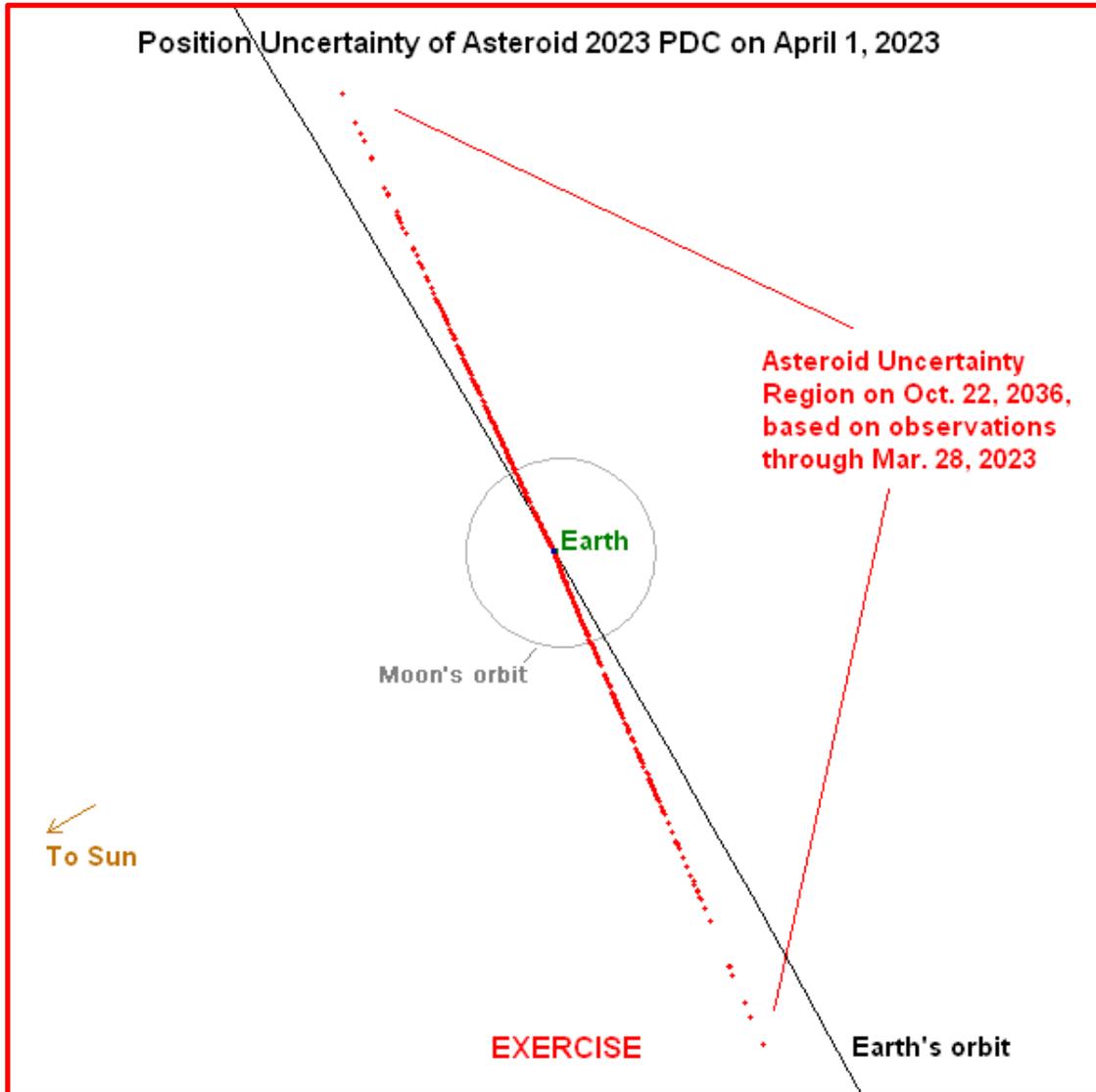
Orbit of Asteroid 2023 PDC Is Earth-Like, but Inclined



- Semi-major axis: 0.99 au
- Orbital Period: 359 days
- Fairly circular: eccentricity: 0.009
- Perihelion/aphelion distances: 0.90 au / 1.07 au
- Orbital inclination: 10.2 deg
- Current distance from Earth: 1.33 au
- Average velocity about Sun is similar to Earth's, just slightly faster
- Asteroid moves very slowly relative to Earth; on average it is now slowly catching up to our planet
 - Last time it was near Earth: the late 1980s
- In 13 years, when the asteroid passes through the orbit intersection point, Earth may be there



Uncertainty in 2023 PDC Position at Potential Impact Point

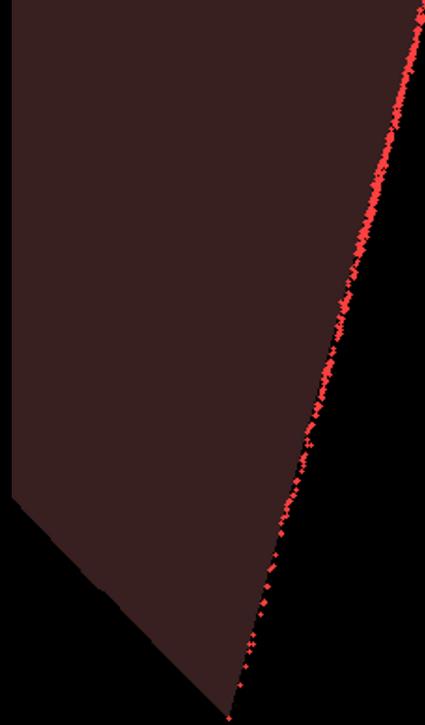


- Based on current tracking, the uncertainty in the predicted position of 2023 PDC on Oct. 22, 2036 is still quite large (note size of Moon's orbit)
- In the diagram, the uncertainty region is traced by a distribution of **red dots**. While the region is continuous, larger spacing between the dots indicates lower probability at those locations
- The region aligns along the asteroid's orbital path: while the orbit itself is quite well determined, the position of the asteroid on its orbit is uncertain
- Currently, only 1% of the red dots intersect Earth
- As time passes and more observations are made, the uncertainty region will shrink
- If the region shrinks with the Earth still near the center, the impact probability will increase



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2023 PDC Uncertainty Region in 2036



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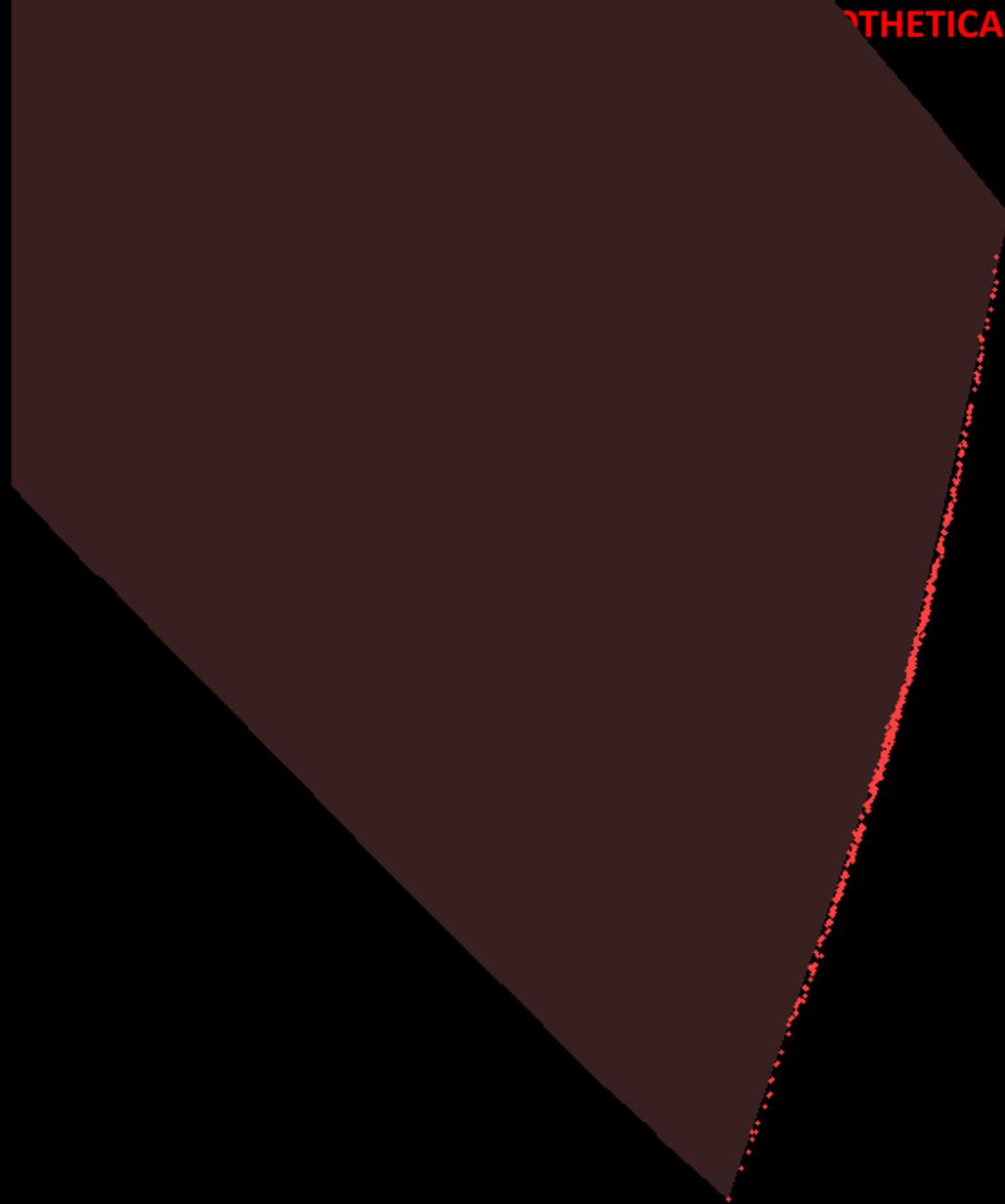


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2023 PDC Uncertainty Region in 2036

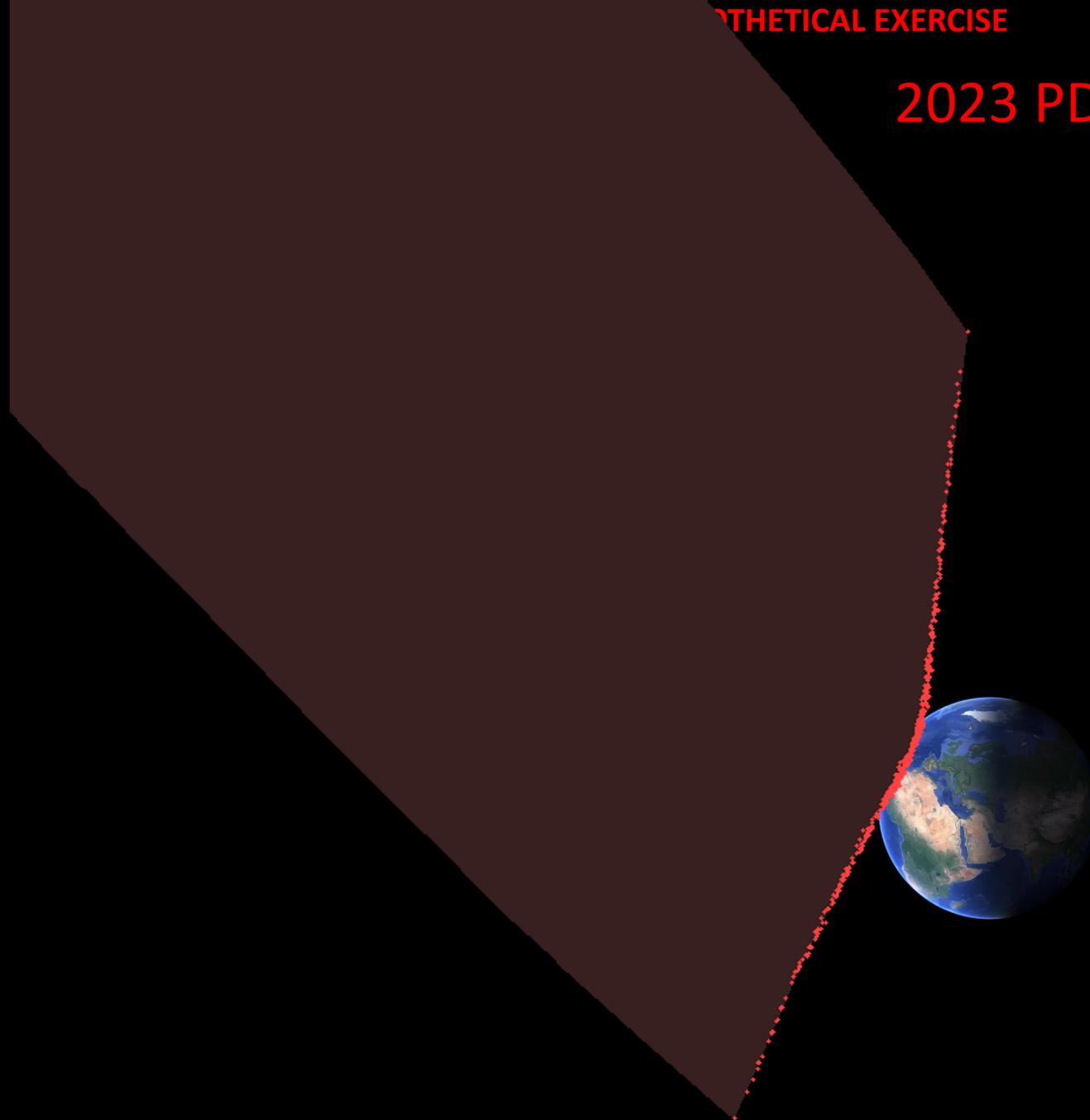


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2023 PDC Uncertainty Region in 2036



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2023 PDC Risk Corridor - West Portion

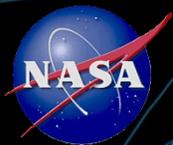


Google Earth

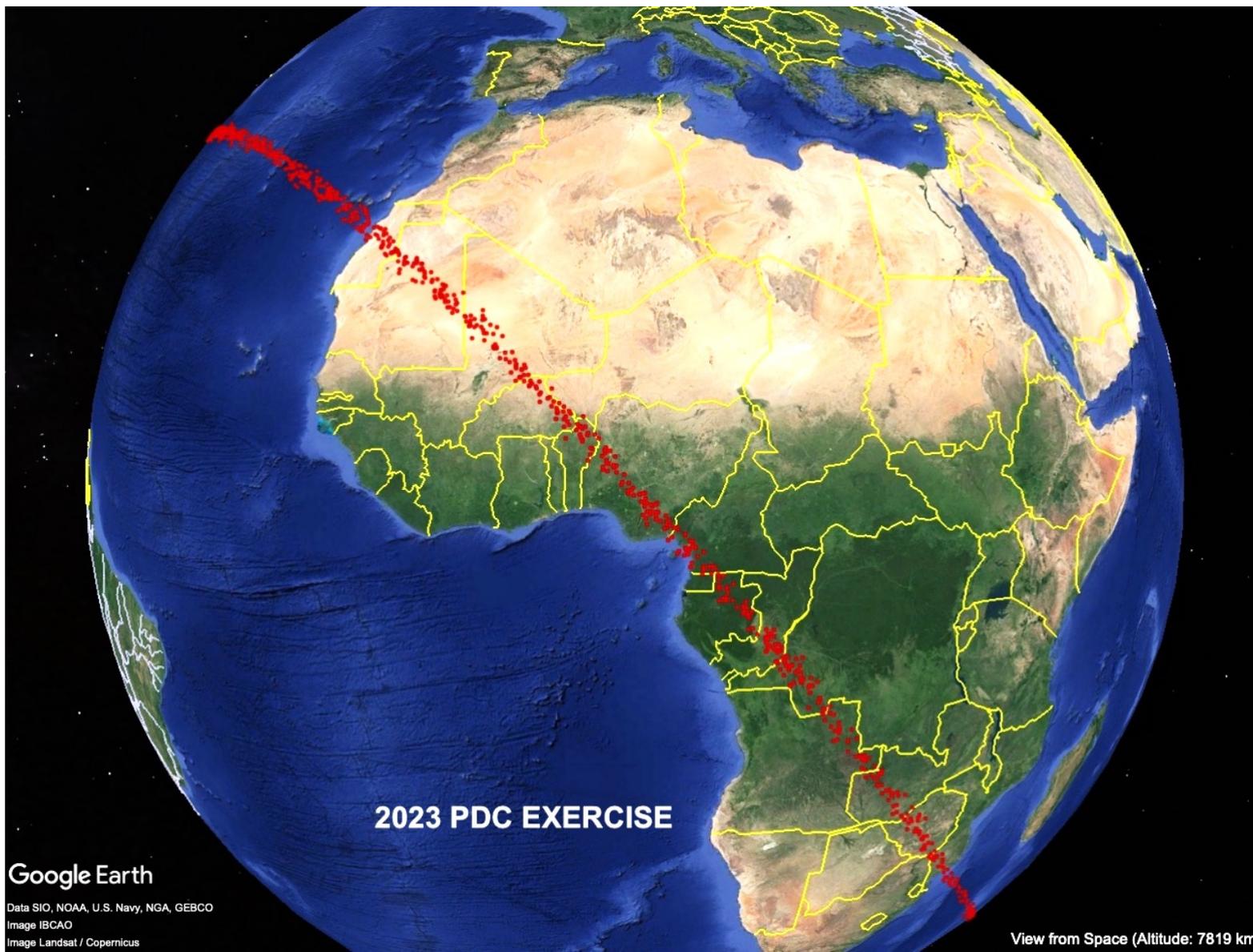
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image IBCAO
Image U.S. Geological Survey
Image Landsat / Copernicus

2023 PDC EXERCISE

View from Space (Altitude: 7819 km)

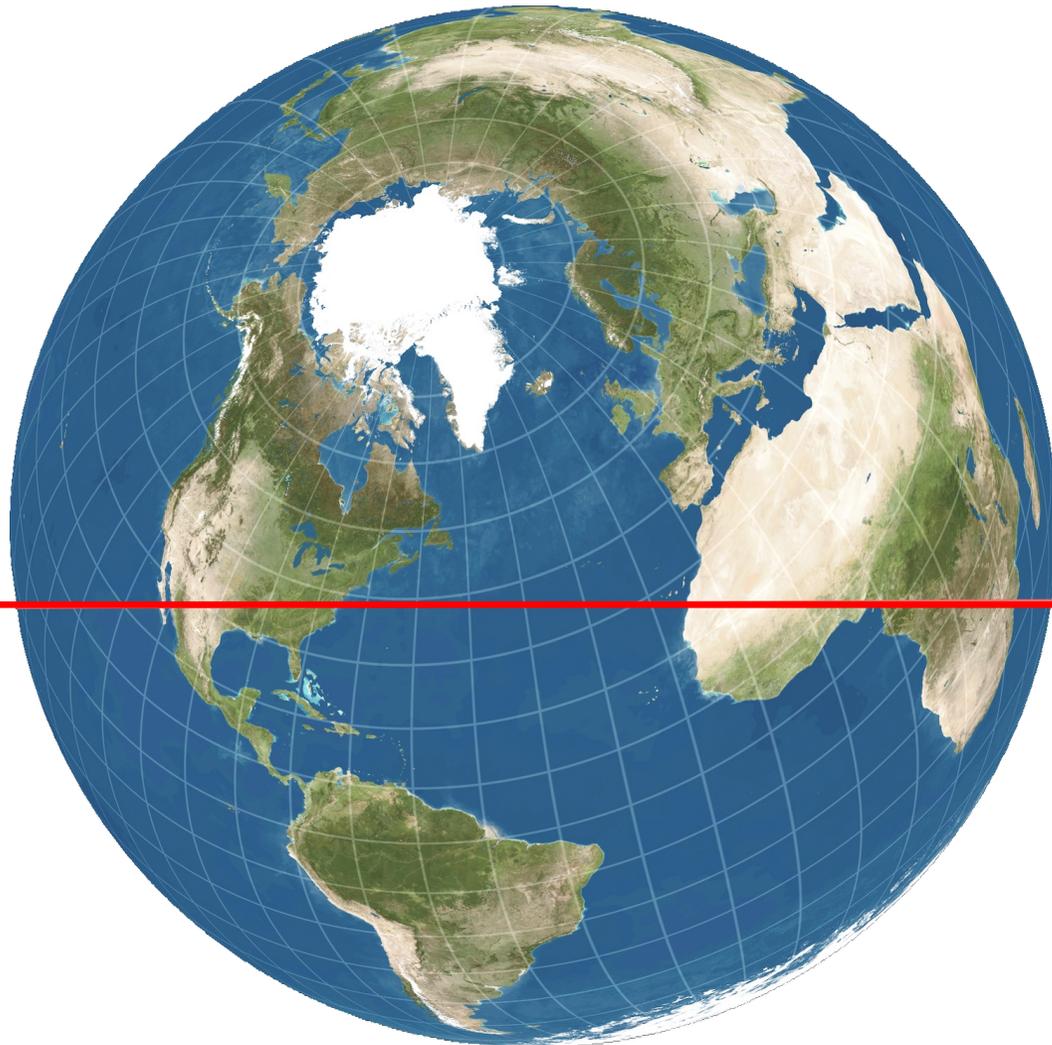


2023 PDC Risk Corridor - East Portion





Asteroid 2023 PDC: Uncertainty in the 2036 B-Plane

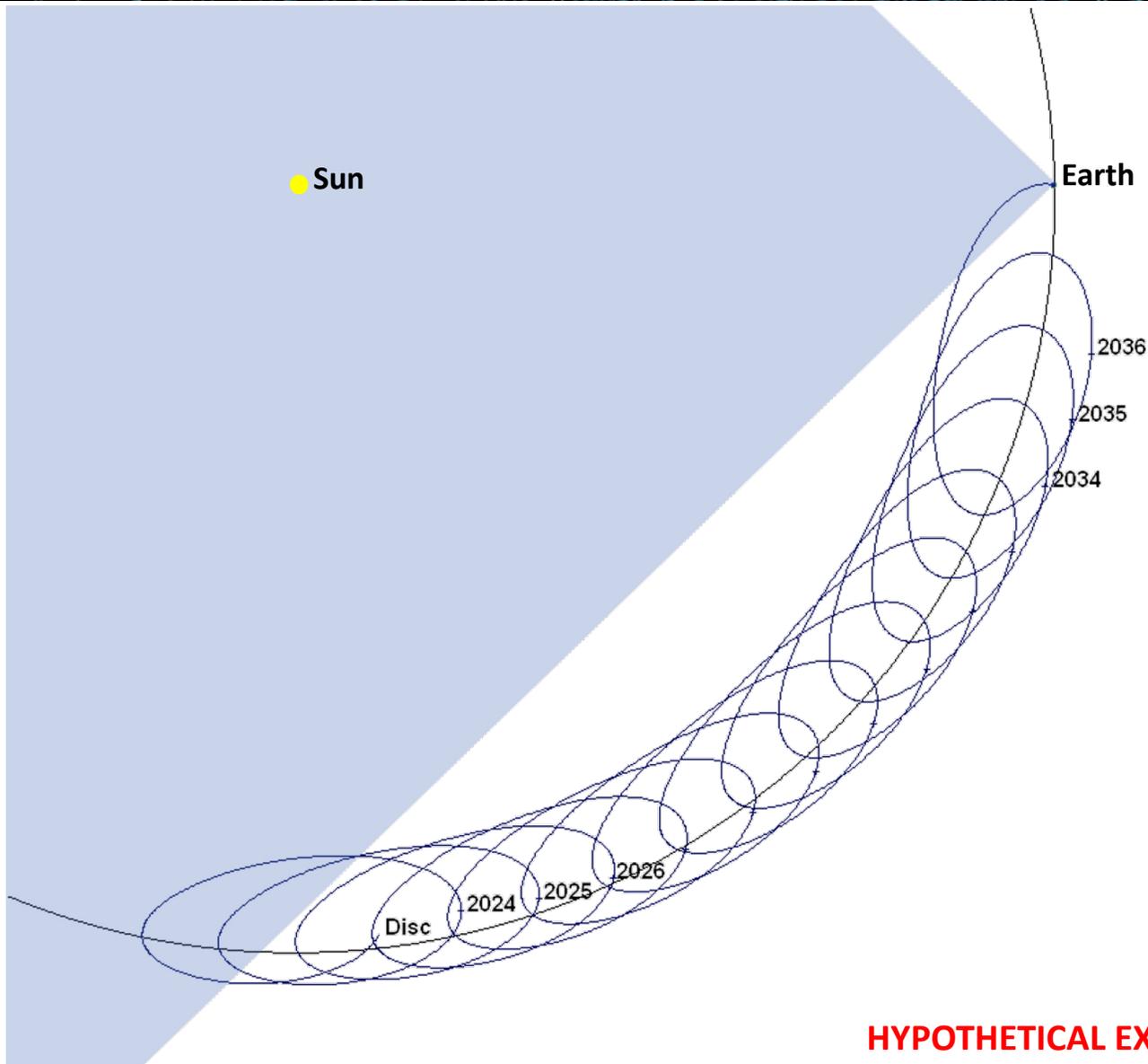


**Uncertainty
Region**

- The B-plane is a useful projection for showing encounter uncertainty and deflection displacement because it removes Earth's gravitational focusing
- This image of the Earth is "unrolled" along the gravitational focusing lines of the encounter; the disc size is about 2.1 times the size of the Earth
- In the B-plane, variations and uncertainties along the asteroid's heliocentric orbit become essentially linear
- The uncertainty region becomes linear (indicated here in red)
- The risk corridor is a chord across the disc: impact could occur at any point along it
- Requirements for deflection are most conveniently expressed as displacements along the red line



Position of 2023 PDC Relative to Earth in a Rotating Frame



This plot shows the position of 2023 PDC **relative to Earth** in a **rotating frame with the Earth-Sun direction fixed**

Because its orbit is slightly eccentric, the asteroid makes yearly epicyclic loops that slowly approach Earth

The asteroid was last in the vicinity of Earth in the early 1980s

Plots in this rotating frame provide a rough indication of when an asteroid is positioned too close to the direction of the Sun to be observed (shaded region)

For roughly half of 2023, the asteroid will be unobservable, but thereafter it will be almost continuously observable

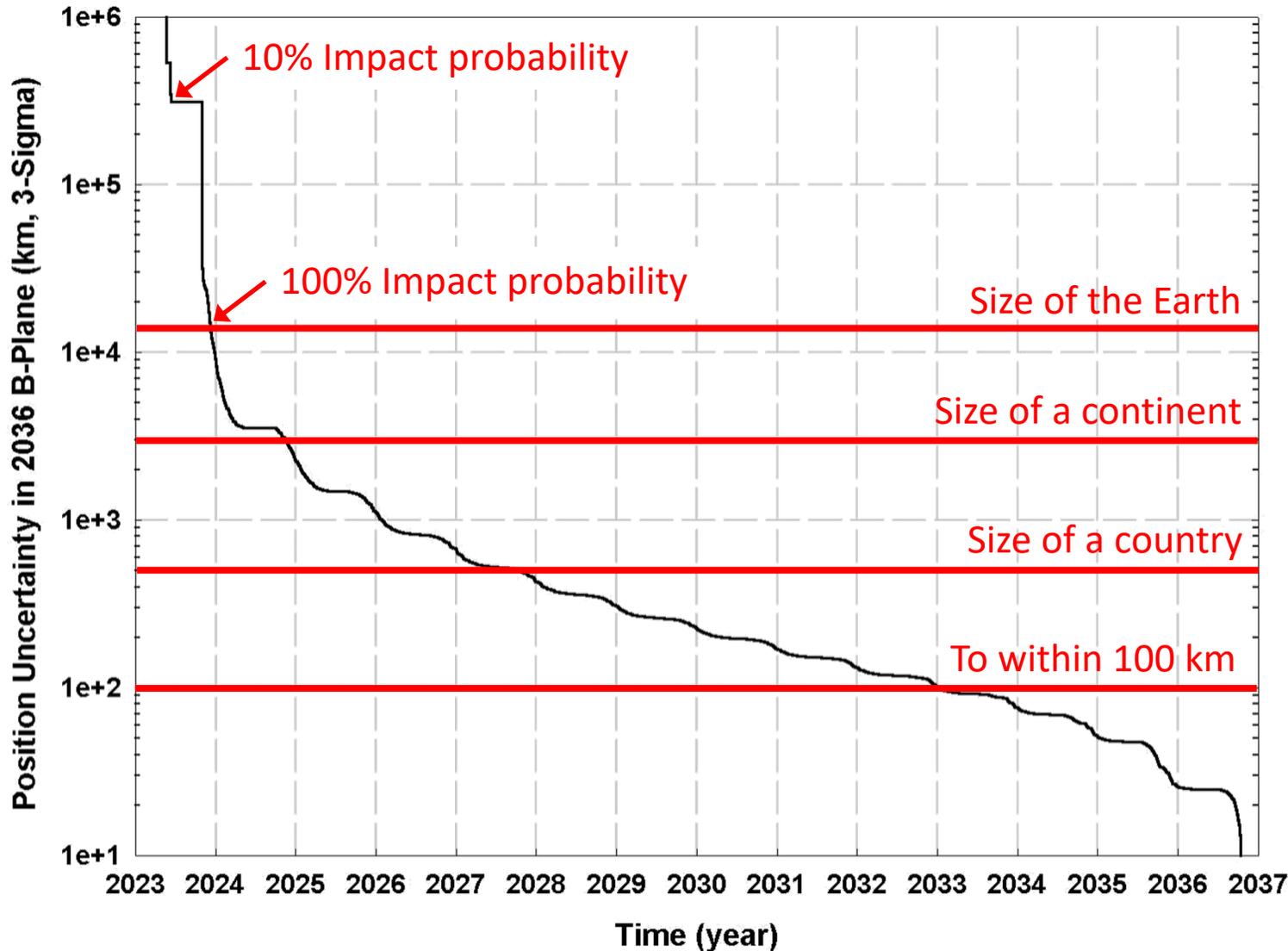


Orbit Improvement in 2023 PDC Can Be Predicted

- As tracking observations are added to the dataset, the accuracy of 2023 PDC's orbit will improve
- The asteroid will be almost continuously observable after late 2023, although it will be distant and quite faint and will likely require large (2-m) telescopes
- The asteroid is too distant for radar observations and will not come within range until 2036
- The dates and accuracies of future optical observations can be approximated, and the rate of improvement in orbit accuracy can be predicted
- The orbit uncertainty is projected into the B-plane to obtain the uncertainty region, and the size of the uncertainty region can be therefore predicted



2023 PDC: Position Uncertainty at 2036 Encounter vs. Time



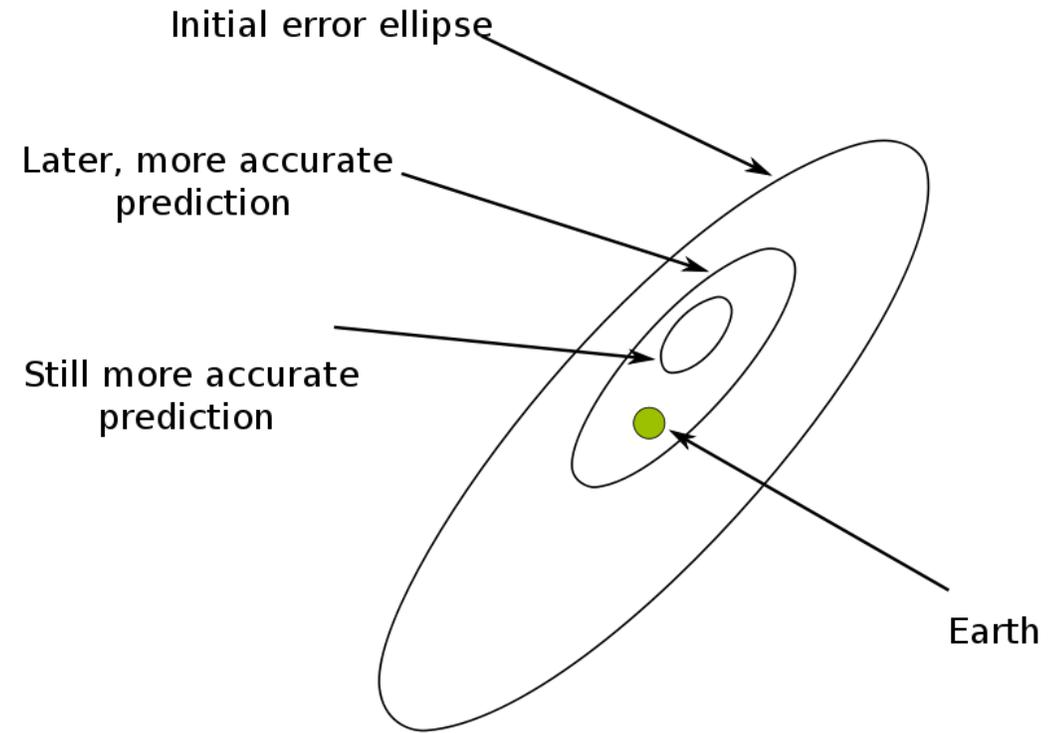
This plot shows the size of the predicted uncertainty in the B-plane as a function of time, assuming only ground-based observations

If the asteroid is headed for Earth impact, we would not know the impact location to 100-km accuracy until 2033



Will Impact Probability Increase or Will It Decrease?

- As 2023 PDC is observed, the accuracy of its orbit improves and the projected size of its B-plane uncertainty region (shown as an ellipse) shrinks
 - For 2023 PDC the ellipse is extremely narrow, essentially becoming a line segment
- Impact probability is computed by integrating the ellipse's probability distribution over the Earth disc
- If the ellipse shrinks away from the Earth, the impact probability will go down
- If the ellipse shrinks with the Earth still inside, the impact probability will grow
- By simulating a **worst-case trajectory** with the Earth at the center of all the ellipses, we can predict **how quickly impact probability might increase** if the asteroid is on a collision course:
 - As high as 10% by July 1, 2023, and 100% probability could be reached by Nov. 1, 2023





2023 PDC: Initial Knowledge of Physical Properties

- Initially, the most of our knowledge of the size comes from measurements of its brightness
- Magnitude measurements are reduced to the parameter H , absolute magnitude, which is essentially the magnitude it would have at standard distances from the Sun and Earth; for 2023 PDC, $H = 19.4 \pm 0.3$
- Absolute magnitude can be used as a **proxy for the size**, provided the mean albedo (reflectivity) is known, but the albedo is essentially unknown, and a full range of possible albedos must be assumed
- If a space-based InfraRed sensor were able to observe, 2023 PDC's size would be much better determined, but it is positioned too close to the Sun to be observed by NEOWISE or JWST
- If NEO Surveyor had been on station, it likely could have observed 2023 PDC, but it has not yet launched
- See the Risk Assessment briefing for a discussion of the estimated physical properties at Epoch 1
- See "Introduction to Asteroid Impact Risk Assessment" for a discussion on physical property estimation